DSN Command System Mark III-78

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DSN Command System Mark III-78 implementation and functional operation are described. Recent software upgrade enables expanded storage capacity in the DSS Command Processor Assembly. Store-and-forward command data handling is operational for Voyager and Helios. Near-real-time command data handling has been retained for Viking and Pioneer.

I. System Functional Description

End-to-end command system operations are represented functionally in Fig. 1. Command sequences for one or more spacecraft are generated and stored at a Mission Operations Center (MOC). Commands for a particular spacecraft are selected from the command files, formatted into messages, and stored for transmittal to a specified Deep Space Station (DSS). Command data is extracted from the messages received at the DSS and stored until radiated. Finally, the commands arrive at the spacecraft and are either executed immediately or stored onboard for later execution.

The functions of the DSN Command System in this process include the following:

(1) Establishing the DSS configuration for the specified spacecraft.

(2) Receiving and storing command data at the DSS.

(3) Queuing command data to be radiated to the spacecraft.

(4) Radiating the command data to the spacecraft.

(5) Monitoring and reporting system status and events.

The Network Operations Control Center (NOCC) provides control and monitoring of the DSN Command System. Instructions from NOCC and command data from MOC are communicated to the DSS via the Ground Communication Facility (GCF) High-Speed Data subsystem (GHS), as shown in Fig. 2.

A detailed diagram of the DSN Command System Mark III-78 is presented in Fig. 3.

II. System Implementation

The equipment configuration for the DSN Command System Mark III-78 (Fig. 3) is the same as the Mark III-77 configuration described in Refs. 1 and 2, except that the DSS pre-and-post detection analog recording (PPR) subsystem has been eliminated. The DSN Mark III data subsystems implementation project was completed with the reconfiguration of the final Deep Space Station, DSS 11, at Goldstone, California, in early 1978. The GCF High-Speed Data Subsystem (GHS) conversion from line-switching to programmable message-switching was completed in mid-1978. The GHS upgrade included implementation of the required interfaces with the Network Operations Control Center (NOCC) and the Mission Control and Computing Center (MCCC). High-speed data for all missions, except Viking, are routed by the message-switching processors. The line-switching interface for Viking data will be maintained until March 1979.

During 1978 the DSS Command Processor Assembly (CPA) software program was upgraded to include the "store-and-forward" data-handling method and increased command storage capacity described in Ref. 3. The JPL Mission Control and Computing Center was reconfigured to provide the required processing functions to utilize the store-and-forward technique for Voyager and Helios spacecraft command operations. The Pioneer and Viking mission operations organizations have chosen to continue to use the older, near-real-time method of command data handling.

Command System testing with the new CPA software was conducted during the period of July through October. The testing included subsystem acceptance tests, system acceptance tests, system performance tests, DSN operational verification tests, interface tests, flight project ground data system tests, and command demonstrations with in-flight spacecrafts. The CPA software was transferred to DSS operational use at the beginning of November.

The testing identified many minor anomalies (which can be avoided by using operational restraints). These remain to be corrected by future program modifications. The anomalies are documented as liens against the development-to-operations transfer agreement. The next update of the CPA software is planned to be operational after the Voyager 2 Jupiter encounter and the Pioneer 11 Saturn encounter.

III. Pretrack System Preparation

DSS pretrack operations performed by station personnel include initializing the CPA software for "phase 1" or "phase 2" operation so that the CPA will be prepared to recognize the content of the high-speed data blocks to be received from NOCC and the flight project command center. Phase 1 initialization is required for the older type of command data messages (Ref. 1); phase 2 initialization is required for the new (store-and-forward) type (Ref. 3). Additional on-site initialization inputs to the CPA specify the flight project name and the spacecraft identification number. These inputs cause the software to transfer a specific configuration and standards and limits table from disk storage to memory and to configure the Command Modulator Assembly (CMA) and CPA according to the table. Changes may later be made by high-speed data messages from NOCC or by keyboard entries at the Data System Terminal (DST) in the station.

Upon initialization, the CPA sends DSS Command Subsystem (DCD) configuration and status information across the star switch controller (SSC) to the DSS Monitor and Control Subsystem (Fig. 4) for inclusion in the monitor data blocks that are periodically transmitted to the NOCC to provide station status displays in the Network Operations Control Area (NOCA). The subsystem configuration and status information are also sent from the CPA to the DST for station display.

Prior to the beginning of the scheduled spacecraft track the control of the station command functions is transferred to the NOCC. Configuration and standards and limits are updated by transmission of high-speed data messages from the NOCC command subsystem (NCD) real-time monitor (RTM) processor. The configuration and standards and limits are derived from files maintained in the Network Support Computer (NSC). Spacecraft-dependent parameters, such as symbol period, command subcarrier frequency, exciter frequency, and appropriate abort limits, are established via these messages. After the proper configuration and standards and limits have been established, test commands are transmitted through the system to ensure that the system can accept spacecraft commands via high-speed data messages, temporarily store the commands, and properly confirm transmission. After NOCC operations personnel have established that the system is operating properly, the system control is transferred to the flight project for transmission of actual spacecraft command sequences during the spacecraft track period.

IV. Command Data Handling

A. Phase 1 Method – Near-Real-Time

With the CPA initialized for phase 1 operation, the data handling method is functionally the same as has been used since 1973. A command stack provides storage of high-speed data blocks (stack modules) of command data. Each stack module consists of up to six command elements. Each command element contains up to 71 bits of command data and, at project option, can be either timed or nontimed.

The top command element in the first stack module is eligible for radiation to the spacecraft. Nontimed commands are radiated immediately after eligibility. Timed commands are radiated after becoming eligible at the time specified in the high-speed data block. At the time for radiation of the command element, the CPA establishes the proper mode (see Fig. 5 for description of the various modes) and configuration of the CMA; then the command is transferred to the CMA for immediate radiation via the Receiver-Exciter, Transmitter, Microwave, and Antenna Subsystems. Related verification, confirmation, and abort criteria (if required) are established by the CPA.

During these command operations, events may occur in which high-speed data message transmission to the NOCC and MOC becomes necessary. The following events initiate message transmission:

(1) Acknowledged receipt of a high-speed data block.

(2) High-speed data block rejection by the CPA.

(3) DSS alarm or alarm clear.

(4) Response to a recall request.

(5) Confirmed command element.

(6) Aborted command element.

B. Phase 2 Method – Store-and-Forward

The new data-handling method associated with phase 2 initialization of the CPA utilizes the CPA disk to provide expanded storage of command data. This method is designed to allow mission operations to prepare large files of spacecraft commands in advance and then to forward several files to the DSS at the beginning of a spacecraft track.

1. Command files. Each file may consist of 2 to 256 high-speed data blocks. The content of each of these data blocks is a file *element.* The first block of each file contains the *header element* and the remaining blocks each contain a *command element.* Each command element may consist of up to 800 bits of spacecraft command data. Up to 8 files for a given mission can be stored by the CPA. Thus, the available storage is greater than 1.6 million command bits.

The header element contains file identification information, file processing instruction, and a file checksum for error protection. The file identification information consists of a file time ID, a file text name, and a project reference number. Once generated (normally by project command generation software), the information is unchanged throughout the ground system. The file processing instructions consist of optional file radiation open and close window times, and an optional file bit 1 radiation time. File open and close window times specify the only time interval during which command elements in the file may begin radiation (i.e., a mission sequence may demand that specific commands *not* be sent before or after certain times). The bit 1 radiation time allows the project to specify the exact time at which the file is to begin radiation to the spacecraft. The file checksum is intended to provide error protection for the end-to-end ground command system. It is created at the time of file generation and is passed intact to the DSS. It adds reliability to insure that no data were dropped or altered in the transfer from one facility to another.

The command elements contain the actual command bits to be radiated to the spacecraft, identification information, and processing-control information. The identification information includes the file time ID and the file text name (same as the header element), project reference number, and element number (1-255). The processing-control information consists of an optional delay time. If the project wants to delay radiation of a command element (delay from the previous command), this delay time would be used.

2. Receiving and storing command data at a DSS. Normally, the file(s) of commands to be radiated to the spacecraft are sent to a DSS during the first few minutes of a spacecraft track (i.e., just after spacecraft signal acquisition). The first step in receiving and storing command data at a DSS is the process of opening a file area on the CPA disk at a DSS. This is accomplished by the Mission Control Center sending a file header element to the DSS CPA. The CPA acknowledges receipt of this *file-open* instruction. The Mission Control Center immediately sends a command file (up to 255 command elements per file). Command element blocks are normally sent at a rate of 3 per second; however, the rate can be increased to a maximum of 5.4 per second if necessary. The Mission Control Center then follows with a *file-close* instruction. The CPA acknowledges the close instruction and indicates file loading successful or unsuccessful. If successful, the Mission Control Center proceeds to send any remaining files (up to 8 total). If unsuccessful, the CPA specifies (in the acknowledge to the Mission Control Center) the reason for the failure and from what point in the file the command elements are to be retransmitted.

There are numerous reasons the CPA rejects the close instruction, but the prime one would be an error occurring in the transmission link between the Mission Control Center and the DSS. The Mission Control Center retransmits the data and again attempts to close the file. Again, after a successful file close, the Mission Control Center proceeds to send any remaining files. Upon successful closing of all files, the loading and storing process is complete. This process will normally take less than 10 minutes to complete. The command data is then available for radiation to the spacecraft.

3. Queuing the command data for radiation. After having loaded the file(s) at the CPA, files may be selected for radiation to the spacecraft. This process is called *attaching.* A five-entry *queue* of file names is provided. The Mission Control Team determines in which order the files are to be attached, normally in the order in which they were sent to a DSS. The order in which they are attached determines the sequence in which they will be radiated: that is, first attached, first to radiate to the spacecraft. Attaching a file to the queue is accomplished by the Mission Control Center sending an attach directive to the DSS CAP. Each file, as it is attached, is placed at the bottom of the queue. After attaching the files, the top file in the queue is eligible for radiation to the spacecraft.

4. Command radiation to the spacecraft. The first command element in the top (prime) file in the queue begins radiation to the spacecraft immediately after attachment or as soon as all optional file instructions are satisfied. As previously stated, a file can have optional instructions – Bit 1 radiation time and file open and close window times. If used, these instructions control when the first command element in the file begins radiation to the spacecraft. The file is defined to be active when the first command element begins radiation. Upon completion of radiation of the first command element, the CPA radiates the second command element either immediately or when the optional instruction delay time has been satisified. The CPA continues to radiate all command elements in the file until complete. After the first file completes the radiation process, the second file in the queue automatically becomes the prime file and the file radiation process is repeated. After the second file completes radiation, the third file becomes prime, etc. This process is repeated until all files in the queue are exhausted. The Mission Control Center can attach new files to the queue whenever space becomes available (i.e., after the first file radiates).

As the radiation of command elements in a file is in process, periodic reporting via high-speed data line messages to the Mission Control Center is accomplished. Transmission of these messages to the Mission Control Center occurs every three minutes, or after five elements have been radiated, whichever occurs first.

5. Additional Data Processing. The functions of storing the command files at a DSS, attaching the files to the queue, and radiating the commands to the spacecraft are rather straightforward and the above descriptions assumed nominal-standard operation of the data processing functions. However, the complexity of the total data processing capabilities is a result of assuming worst case, failure-recovery, or non-nominal operating conditions. Numerous data processing capabilities exist to accommodate these conditions. Below is a list of the optional or non-nominal data processing functions.

a. File erase. The capability exists to delete a file from storage at the DSS CPA. This *erase* function can be accomplished either locally at a DSS or via high-speed data message from the Mission Control Center. It is expected that files will be stored on disk at the CPA that are not intended to be radiated to the spacecraft. Examples: Test files left from pretrack testing or the Mission Control Center sends wrong files to DSS. The file erase function is provided so that unnecessary files stored at the DSS can be deleted to make room for files intended for radiation to the spacecraft.

b. Clearing the queue. Files could be attached to the queue out of order. As previously stated, the order of file radiation to the spacecraft is dependent on the order of files in the queue. The queue can be cleared by a high-speed data *clear-queue* message from the Mission Control Center.

c. Suspend radiation. If for some reason, Mission Control desires to stop command radiation, a *suspend* message can be sent from the Mission Control Center. This message stops command radiation to the spacecraft. The file is defined as being in the suspended state.

d. Resume command radiation. To *resume* radiation of a suspended file (either suspended intentionally or from an abort), a message can be sent from the Mission Control Center to resume radiation at a specific element in the file.

e. Command abort. As each command bit is radiated to the spacecraft, numerous checks are made to insure validity of the command data. If a failure is detected during radiation, the command element is *aborted.* Optional methods of treating an abort are provided. Automatic recovery can be attempted (resend the command element) or radiation is terminated until operator intervention occurs. If radiation ceases, again the file is said to be suspended.

f. Close window time override. The close window time (previously discussed) can cause an actively radiating file to become suspended. If this occurs, Mission Control can send a message to the DSS CPA to *override* this time. The close window time override directs the CPA to ignore the close window time and proceed to radiate the complete file.

Most of the imperfections that exist in the currently operational CPA software program are in this area of real-time file manipulation and in the details of status and event reporting. The known discrepancies will be corrected in a future CPA software upgrade.

V. Data Records

All high-speed data blocks received by the CPA and all high-speed data blocks sent from the CPA are logged at the

DSS on the Original Data Record (ODR) by the Communications Monitor and Formatter (CMF). The CPA has the capability to record a temporary ODR on disk, if the CMF ODR is disabled.

High-speed data blocks received at the GCF central communications terminal, from all DSSs, are recorded on the Network Data Log (NDL) at the Network Log Processor (NLP). The NLP also logs all command system high-speed data blocks transmitted to the DSS from NOCC or any MOC.

The ODR and the NDL provide a source of information for fault isolation in case of system failure.

References

1. Stinnett, W. G., "DSN Command System Mark III-75," in *The Deep Space Network Progress Report 42-29*, pp. 5-9, Jet Propulsión Laboratory, Pasadena, Calif., Oct. 15, 1975.
2. Stinnett, W. G., "Mark III-77 DSN Command System," in *The Deep Space Network Progress Report 42-37*, pp. 4-11, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1977.
3. Stinnett, W. G., "DSN Command System Mark III-78," in *The Deep Space Network Progress Report 42-43*, pp. 4-8, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1978.

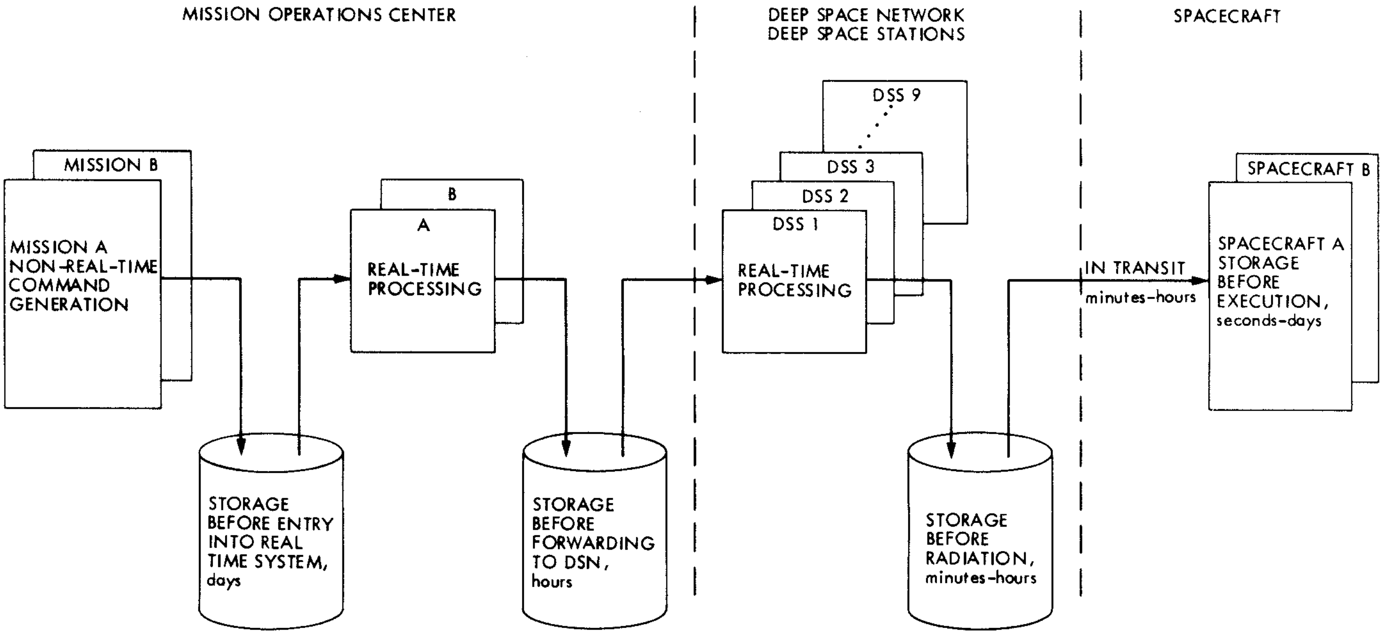


Fig. 1. End-to-end command data flow – typical storage times

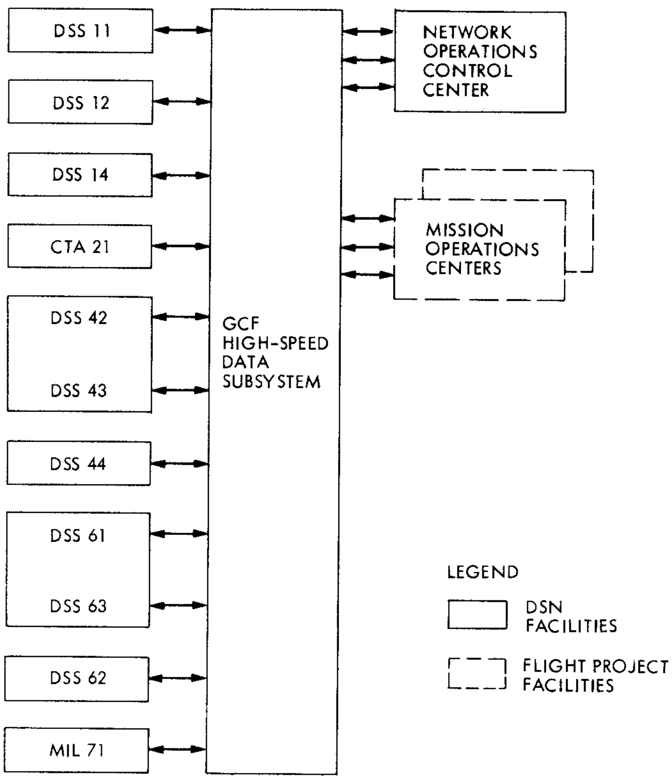


Fig. 2. Facilities which participate in command operations

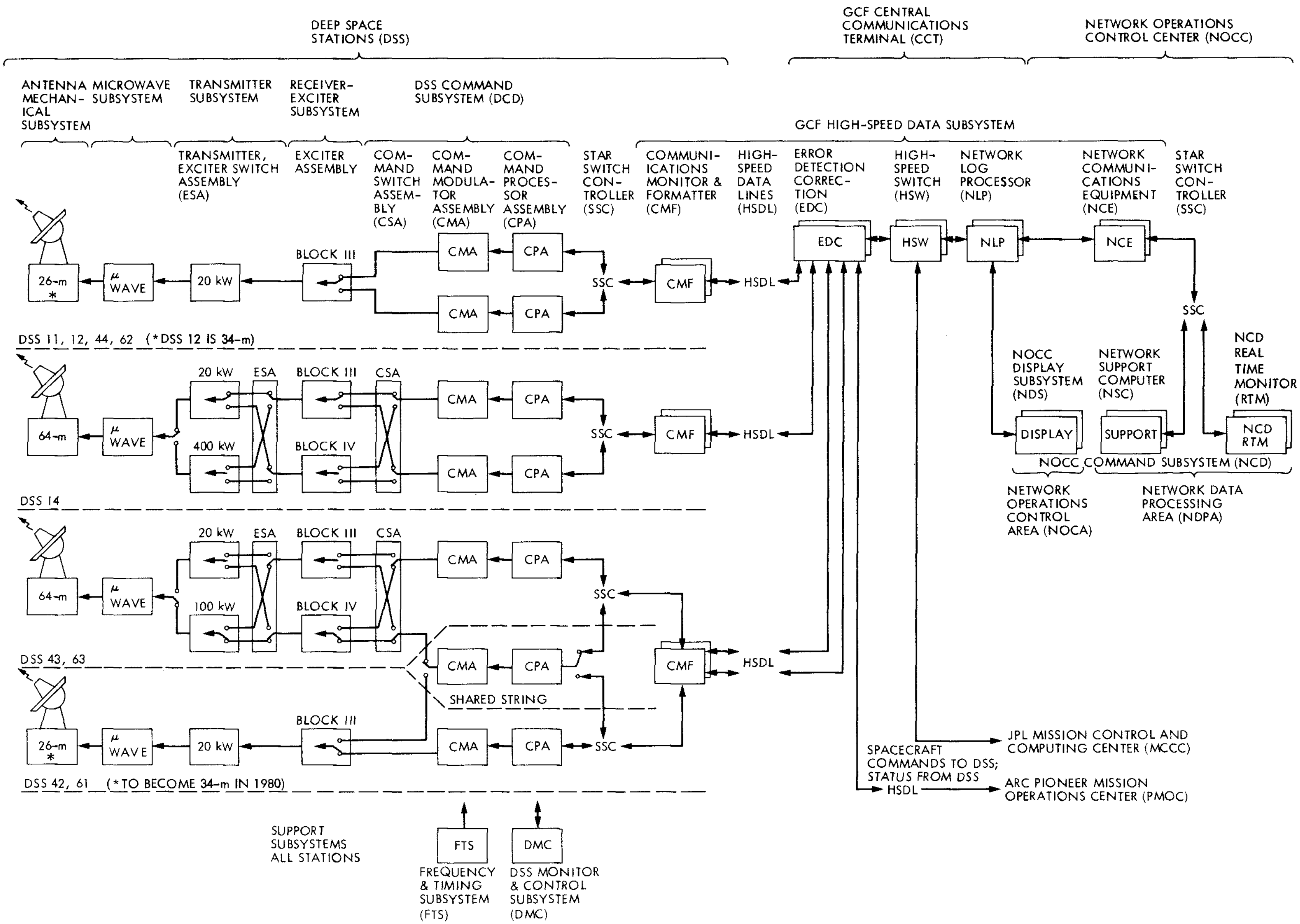


Fig. 3. DSN Command System Mark III-78

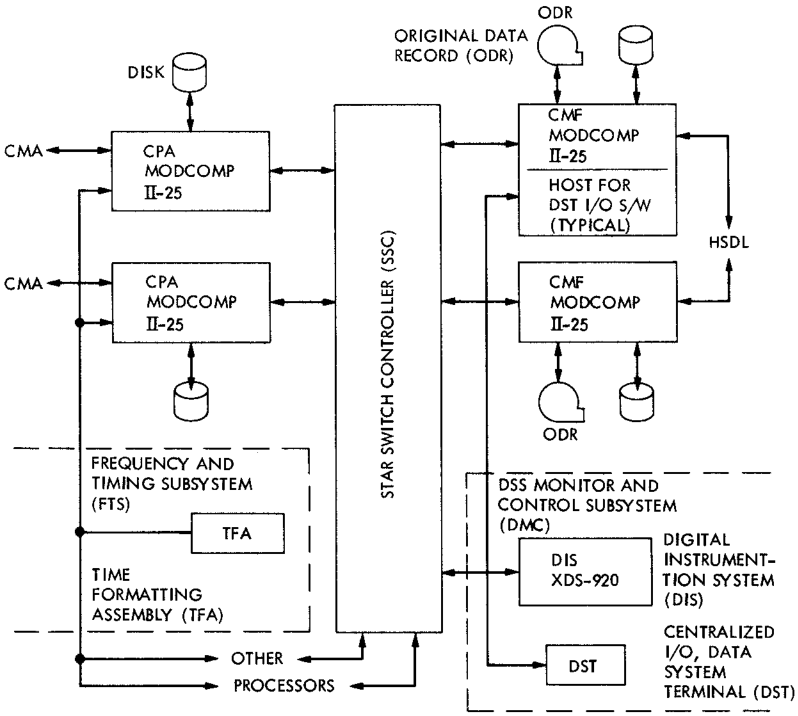
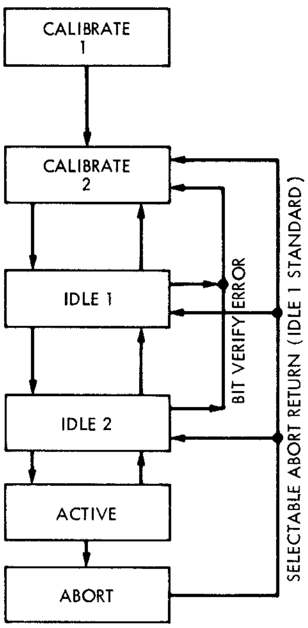


Fig. 4. Deep Space Station implementation details



CPA MODE	PRIME PURPOSE	DATA ACCEPTED VIA HIGH SPEED	COMMENTS
CALIBRATE 1	ALLOWS DSS OPS PERSONNEL TO PERFORM INITIALIZATION TASKS	CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL	UPON RECEIPT OF A STANDARDS AND LIMITS AND CONFIGURATION HSD BLOCK, THE CALIBRATE 2 MODE WILL BE ENTERED
CALIBRATE 2	STANDARD MODE FOR UPDATING STANDARDS AND LIMITS AND CONFIGURATION DATA VIA HIGH SPEED PRIOR TO SPACECRAFT ACQUISITION	CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL	MULTIMISSION STANDARD PROCEDURES SHOULD STATE THAT THIS MODE IS TO BE ENTERED FOR CHANGING SUBCARRIER FREQUENCY, BIT RATE
IDLE 1	SAFE MODE - CANNOT COMMAND. PROVISION FOR IDLE/ACQUISITION SEQUENCE. ALLOWS CONFIGURATION AND STANDARDS AND LIMITS TO BE CHANGED	CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL	ALL STANDARDS AND LIMITS AND CONFIGURATION DATA PARAMETERS WILL TAKE IMMEDIATE EFFECT IN THIS MODE
IDLE 2	ALLOWS ENTRY INTO ACTIVE MODE. PROVIDES IDLE/ACQUISITION SEQUENCE DURING COMMAND PERIODS	RECALL AND MODE CONTROL DATA ONLY	MODE CONTROL DATA CONTAINED IN THE COMMAND ELEMENT BLOCK
ACTIVE	COMMAND TRANSMISSION	RECALL AND MODE CONTROL DATA ONLY	
ABORT	PROVIDES ABORT INSTRUCTION TO CMA	RECALL AND MODE CONTROL DATA ONLY	

NOTES: 1. COMMAND DATA MESSAGES WILL BE ACCEPTED IN ALL MODES
2. ALARM MESSAGES/ALARM DATA WILL BE TRANSMITTED TO THE MOC IN ALL MODES EXCEPT ABORT

Fig. 5. DSN Command System mode descriptions